REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 14. Period--October 1 to December 31, 1944

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The material in this report consists largely of unpublished data ~~and should be kept confidential~~. It is made available in its present form for the convenience of the various State and Federal Agencies concerned with the preservation of stored grain from insect damage.

WHEAT STORAGE

Observations on the Insect Populations in Wheat Stored Under Different Systems of Management*

During December, average samples were taken from the bins remaining in the management series on the Hutchinson Experimental Wheat Storage site. These samples consisted of one quart (approx. 1,000 grams) of wheat taken from the center, north, east, south, and west quadrants of the bins. Five one-quart samples were taken from 1,000-bushel bins and ten one-quart samples from 2,740-bushel bins. The insect population was determined by sifting the individual quart samples and recording the number and kind of insects in each of them. In this manner the location and degree of infestation was determined for each bin together with the average for the bin. The results are given in table 1. It is of interest to note the low level of insect populations in the "Fumigation in September" series which is fumigated with carbon tetrachloride at a dosage of only 2 gallons per 1,000 bushels.

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* -- Reported by H. H. Walkden and R. B. Schwitzgebel, U. S. Dept. of Agriculture, Bureau of Entomology and Plant Quarantine in cooperation with the Bureau of Plant Industry, Soils, and Engineering.

Table 1: -- Insect populations in wheat stored in steel bins remaining in the Management Series, Hutchinson, Kansas, December, 1944

Bin No.	Crop year	Capacity bushels	Insects per 1,000 grams (number)	Remarks
1. No treatment after initial fumigation when bins were filled.				
½-3	1943	1000	1.0	9% moisture content
½-6	1943	1000	0.6	do
6-5	1940	2740	10.3	L-tube ventilation
5-12	1941	5000	0	Bolted tank, painted white, sealed
2. Fumigation when necessary.				
½-2	1940	1000	9.0	Walls and roof painted Aug. 1941
1-2	1940	1000	0	white Mar. 1943
1-3	1940	1000	6.0	do Mar. 1943
11-9	1941	2740	1.6	do Mar. 1943
12-8	1941	2740	3.1	do Mar. 1943
7-8	1940	2740	0.1	Walls and roofs painted
7-9	1940	2740	0.5	white, bins grouped for
8-7	1940	2740	0.8	shading, March 1943.
8-8	1940	2740	1.3	do
3. Turning, cleaning, and fumigation in September.				
3-14	1940	1000	0	
6-11	1940	2740	0.4	
5-7	1940	2740	1.0	
4. Fumigation in August and October.				
2-12	1940	1000	0.4	Bins in this series fumigated
3-12	1940	1000	0.2	with 3:1 mixture of ethylene
½-5	1943	1000	0	dichloride and carbon tetra-
4-5	1943	1000	0	chloride, 4 gals. per 1,000
9-1	1940	2740	0	bushels
10-1	1940	2740	0	do
10-2	1940	2740	0	do
9-2	1940	2740	0	Solid L-tube ventilation
10-3	1940	2740	0	do
9-3	1940	2740	0	Perforated L-tube ventilator.

(continued)

Table 1, continued

Bin No.	Crop Year	Capacity bushels	Insects per 1,000 grams (number)	Remarks
		5. Fumigation in September.		
3-13	1940	1000	1.2	Bins in this series fumigated
4-12	1940	1000	0.8	with carbon tetrachloride, 2
11-2	1940	2740	1.8	gals. per 1,000 bushels.
12-2	1940	2740	0.6	do
11-10	1941	2740	0	do
11-11	1941	2740	0.3	do
7-3	1943	2740	0.1	do
7-4	1943	2740	0.1	do
		6. For observations on rate of deterioration after treatment of assigned treatment.		
3-10	1940	1000	58.8	No treatment after initial
3-11	1940	1000	36.8	fumigation.
1-16	1940	1000	17.8	Germination, 0; for milling
2-16	1940	1000	15.6	and baking tests
7-2	1940	2740	1.6	Surface oil spray; moisture 10%

Five species of stored grain insects were found in the samples. These are listed in table 2.

Table 2: -- Comparative abundance of the different species of stored grain insects in stored wheat, Hutchinson, Kansas, December 1944.

Species	Average number per 1,000-gram sample
Flat grain beetle (Laemophloeus minutus Oliv.)	0.84
Longheaded flour beetle (Latheticus oryzae Waterh.)	0.55
Red flour beetle (Tribolium castaneum Hbst.)	0.47
Lesser grain borer (Rhyzopertha dominica F.)	0.26
Sawtoothed grain beetle (Oryzaephilus surinamensis L.)	0.03

Study of the Fluctuation of Insect Populations in Wheat Stored in Ever-Normal Granary Type Bins

The study of insect population fluctuations in wheat stored in ever-normal granary type bins was continued during the past quarter. Five-probe samples were taken from the upper southwest quadrant of 36 bins in the Management Series and a record made of the number of each species of stored grain insects. A summary of the data obtained during the past nine months is presented in table 3 and arranged to show the effect of different grain storage practices on insect populations.

For the purpose of this table the lesser grain borers and rice weevils were considered "weevils" and all other species were combined as "bran bugs". Rice weevils were rarely taken and the flat grain beetle, sawtoothed grain beetle and longheaded flour beetle were the principal bran bugs.

The only untreated grain which failed to develop serious insect populations throughout the entire season was the 9-10 per cent moisture wheat in unpainted bins and also all grain stored in bins with white walls and roofs. The lesser grain borer populations were especially low in these bins. The other grain storage practices -- fumigation in August and October; fumigation in September; and turning, cleaning and fumigation in September -- reduced the insect populations to a very low level so that the grain entered the winter season in good condition.

As shown by the data of table 3 fumigation in August and October kept the infestation at a lower level during the entire season than either fumigation in September or turning, cleaning, and fumigation in September. It should be noted, however, that bins fumigated in September were treated with a dosage of 2 gallons of carbon tetrachloride per 1,000 bushels, which is not equivalent to the 4 gallon dosage of the 3-1 mixture of ethylene dichloride and carbon tetrachloride applied to the bins fumigated in August and October.

Table 3: -- Summary of the insect populations in the upper southwest quadrant of steel and wood bins, Hutchinson, Kansas, 1944.

Grain storage practice	Average number of insects per 1,000-grams											
	Apr. 1	June 3	July 1	July 15	Aug. 1	Aug. 15	Sept. 1	Sept. 15	Oct. 1	Oct. 15	Nov. 11	Dec. 27
1000-bushel steel bins												
No treatment:												
9.3% moisture	0	0	0.2	0.2	0.4	0.8	1.8	2.4	1.8	2.4	0.4	0.4
	0	0	0.6	0.6	1.8	1.0	1.8	0.4	0.8	1.2	0.6	1.0
10.8% moisture		0	0	1.2	5.6	7.6	14.8 F	(Terminated)				
		0	3.2	5.2	12.8	9.2	9.2					
11-11.5% moisture	0.1	0.2	0.3	1.5	6.0	6.0	43.5	10.3	28.8	12.8	10.0	5.8
	1.6	5.8	11.4	20.0	40.8	20.6	57.2 *	29.3 **	63.2	36.4	34.2	28.2
12% moisture	0	0	0	1.4	4.8	4.2	11.8 F	(Terminated)				
	0.4	0	2.0	8.6	18.0	33.0	53.2					
White walls and roof	0	0	0	0.2	0	0	3.6	1.0	1.2	0.4	0.6	0
	0	1.8	1.6	1.4	3.6	5.6	17.4	10.4	6.8	6.4	9.6	2.6
Fumigation in September	0	0	0	0.4	2.8	8.2	24.2 F	0.4	0.4	0.6	1.0	0.2
	0	0	0.2	3.6	12.6	22.4	82.8	0.8	1.2	1.8	6.2	1.4
Fumigation in August and October	0	0	0	1.5	2.0	3.3 F	0.2	0.3	0.3	0.3 F	0	0
	0	0	2.2	6.5	8.7	11.6	0.3	0.8	0.6	0.5	0.5	0.1

(continued)

Table 3. continued.

Grain storage practice	Average number of insects per 1,000-grams: Apr. 1	June 3	July 1	July 15	Aug. 1	Aug. 15	Sept. 1	Sept. 15	Oct. 1	Oct. 15	Nov. 11	Dec. 27
Turn, clean, and fumigate in September	0	0	0	0.4	4.4	2.4	8.8 T	2.0 F	0.4	0.4	1.2	0
	0	0.4	0	3.6	6.8	11.2	19.2	1.2	0.4	0	0	0.2
2740-bushel steel bins												
No treatment												
10.5-11% moisture	0	0	0.2	0.3	2.2	3.8	10.5 F	(Terminated)				
	0.1	0.6	1.5	10.7	11.1	20.2	21.2					
11-11.5% moisture	0	0	0.2	1.2	3.7	2.6	9.8 F	(Terminated)				
	0.2	0.9	2.3	2.7	5.4	7.5	19.8					
White walls and roof	0	0	0	0	0	0	0	0	0	0	0.1	0
	0.5	0.5	0.1	0.6	3.3	8.8	7.2	5.9	5.2	3.5	2.6	1.5
Painted white and grouped for shading	0	0	0	0	0	0	0	0.3	0.1	0.1	0.3	0
	0.5	0.6	0.6	1.1	2.2	1.4	4.0	2.3	3.5	1.0	1.1	0.6
Fumigation in September	0	0	0.1	0.2	1.0	3.2	7.5 F	1.2	0	0.7	0.1	0.1
	1.8	0.3	4.6	2.7	5.8	9.3	11.8	1.8	0.8	1.7	0.4	0.4
Fumigation in August and October	0	0	0	1.1	1.1	5.5 F	0	0.2	0.2	0 F	0	0
	0	0	0	0.6	2.2	11.0	0	0.2	0.5	0.1	0	0

(continued)

Table 3, concluded

Grain Storage Practice	Average number of insects per 1000-grams											
	Apr. 1	June 3	July 1	July 15	Aug. 1	Aug. 15	Sept. 1	Sept. 15	Oct. 1	Oct. 15	Nov. 11	Dec. 27
Turn, clean, and fumigate in September	0	0	0.5	0.7	6.3	11.7	61.4 T.	3.5 F.	0.1	0	0.1	0
	3.6	0.2	13.5	32.6	87.9	33.2	80.9	14.9	0.2	0	0.1	0.2
1500-bushel wood bins												
White walls and roof	0	0	0	0	0	0	0	0.6	0.4	0	0.8	0
	0	0	1.0	2.8	10.4	21.6	21.2	31.0	17.4	14.6	34.4	25.6
White walls	0	0	0	0	0.2	2.8	0.6	4.0	4.2	2.0	1.6	0.6
	0	0	1.2	4.4	7.3	12.4	47.2	19.8	22.8	25.6	8.0	4.8
Red walls	0	0.2	0.2	0	1.2	4.6	2.8	6.6	5.6	3.6	3.6	1.0
	0.4	0.2	6.8	11.8	55.0	62.0	60.4	58.8	80.2	41.4	22.0	10.2

Legend:

* = Weevils: includes lesser grain borer and rice weevil.
** = Bran bugs: all species except the weevils.
* = Fumigated two of six bins.
** = Fumigated two of four remaining bins.
F = Grain fumigated.
T = Grain turned and cleaned.

Study of the Migration of Stored Grain Insects by Means of Bin Ventilator Traps

During the past season bin ventilator traps were employed to study the migration of stored grain insects into a galvanized bin and a bin painted white. The bins were tightly calked to prevent the entrance of insects except through the ventilators which were fitted with traps to retain the insects entering in this manner. The traps were in operation from July 3 to November 13. The catches were examined at weekly intervals throughout the season and the results are summarized in tables 4 and 5.

A total of 1353 insects were taken in the two traps during the season with more than 75 per cent of the catch taken in the unpainted bin. Large catches were recorded from the last of July through October in this unpainted bin whereas over half the total catch for the white bin occurred in August. Probably the most significant fact in this study was that more than thirty times as many lesser grain borers migrated into the unpainted bin than were taken in the trap in the bin which was painted white. This species has continued to be the most serious stored grain pest at the Hutchinson site since its erection in 1941. Any measure to prevent or to reduce the activity of this pest is of high importance in the storing of grain in southern Kansas, Oklahoma, and Texas.

Table 4: --- Number of insects entering ventilator traps in bins at Hutchinson, Kansas, 1944.

Period	Bin 1-1 Galvanized walls and roof		Bin 1-2 White walls and roof	
	No. insects	% of total	No. insects	% of total
July 3-10	47	4.5	1	0.3
10-17	49	4.6	10	3.3
17-24	24	2.3	7	2.3
24-31	117	11.1	5	1.7
July 31-Aug. 7	49	4.6	12	4.0
Aug. 7-14	158	15.0	86	28.7
14-21	41	3.9	25	8.3
21-28	36	3.4	29	9.7
Aug. 28-Sept. 4	85	8.1	29	9.7
Sept. 4-11	48	4.6	12	4.0
11-18	54	5.1	24	8.0
18-25	89	8.5	10	3.3
Sept. 25-Oct. 2	27	2.6	8	2.7
Oct. 2-9	32	3.0	12	4.0
9-16	47	4.5	16	5.3
16-28	123	11.7	9	3.0
Oct. 28-Nov. 8	22	2.1	6	2.0
Nov. 8-13	4	0.4	0	0.0
Totals	1052		301	
Per cent of total		77.8		22.2

Table 5: -- Comparative abundance of the species of stored grain insects taken in ventilator traps, Hutchinson, Kansas, 1944

Species	Total catch			Per cent of catch		
	Bin 1-1	Bin 1-2	Total	Bin 1-1	Bin 1-2	Total
Flat grain beetle	590	278	868	56.1	92.4	64.2
Lesser grain borer	430	13	443	40.9	4.3	32.7
Foreign grain beetle	15	2	17	1.4	0.7	1.3
Hairy fungus beetle	10	1	11	1.0	0.3	0.8
Red flour beetle	4	1	5	0.4	0.3	0.4
Rice weevil	2	3	5	0.2	1.0	0.4
Longheaded flour beetle	0	3	3	0.0	1.0	0.2
Sawtoothed grain beetle	1	0	1	0.1	0.0	0.1
Totals	1052	301	1353	77.8	22.2	

Control of Insects in Farm Stored Grain

Various interior wall treatments have been applied in farm bins and have been discussed in Reports 12 and 13. During November the bins were sampled to determine the kind and degree of insect infestation, and in the more heavily infested bins estimates of the amount of damage to the grain were made. The infestation in the different bins is summarized in table 6. It may be noted that the greatest number of dead insects was found near the walls treated with DDT.

The cadelle (Tenebroides mauritanicus L.) was the most abundant species found in farm bins during November. The most intense infestation was found in the west bin on the Oldenettel farm. Quart samples were taken just below the surface next to the walls in this bin. Sub-samples were cut from these and the number and weight of insect-damaged kernels were determined.

The results are given in table 7. The wheat was of the 1944 crop and the bin was filled at harvest late in June, 1944. It may be noted from the table that about 4 per cent of the wheat in the center of the bin has sustained damage after about 5 months of storage. Next to the walls, on a weight basis, the damage ranged from about 4 per cent to more than 7 per cent. It should be borne in mind that the above figures represent the most extreme case observed thus far, and the damage is much less in the majority of farm bins.

Table 6: -- Effect of various wall treatments on insect infestation in farm stored wheat, Reno County, Kansas.

Wall treatment	Number of insects per 1000 grams surface sample next to wall					
	August		September		November	
	Living	Dead	Living	Dead	Living	Dead
Oldenettel, west bin						
Whitewash	22	3	96	4	13	10
Red barn paint	14	0	48	0	8	11
White lead paint	34	1	42	4	10	8
Dendrol-lye	34	2	42	58	10	13
DDT	29	72	10	70	18	218
Oldenettel, east bin						
K-655	0	0	12	0	1	1
Untreated check	0	0	10	0	1	2
Dendrol-lye	0	0	8	4	4	21
K-1127	0	0	6	0	4	10
K-208	0	0	6	0	0	0
Deobase oil	0	0	4	2	4	4
DDT	19	155	4	32	4	114
Swanson granary						
Untreated check	0	0	12	0	16	1
Deobase oil	0	0	6	0	10	4
DDT	0	0	4	0	2	10
Swanson, west box car						
Dendrol-lye, south wall	2	0	42	4	11	6
Dendrol-lye, west wall	16	0	16	0	19	7
Dendrol-lye, east wall	0	0	14	0	0	0
Swanson, east box car						
DDT, west wall	14	0	6	0	0	26
DDT, south wall	0	0	4	0	3	19
DDT, east wall	0	0	2	0	Not sampled	
DDT, north wall	0	0	0	0	0	10
Gump granary						
DDT	0	0	6	0	2	5
Red barn paint	0	0	4	0	0	0
White lead paint	0	0	2	0	0	0
Whitewash	0	0	0	0	1	1

Table 7: -- Amount of insect damage to wheat stored in a farm granary with treated walls, November, 1944.

Wall treatment	Weight of sample (grams)	Number of kernels	Per cent damage	
			Weight basis	Number basis
Oldenettel, west bin				
Dendrol-lye	45.00	1487	7.4	9.9
DDT	43.75	1680	6.6	7.7
Wheat lead paint	43.75	1644	5.9	7.6
Whitewash	43.10	1537	4.9	6.3
Red barn paint	42.60	1530	3.8	4.4
Sample from center of bin	44.00	1548	3.6	4.3

Experimental Fumigation of Wheat

During the past quarter a total of 27 bins, aggregating nearly 36,000 bushels of wheat, have been fumigated experimentally. The majority of the bins were located on the farm, and were made available through the cooperation of Reno County farmers. The results of the experimental fumigation work are given in table 8, parts 1 (steel bins), and 2, (wooden bins).

Part 1. Experimental Fumigation of Wheat Stored in Steel Bins. (Table 8, part 1.)

Using a dosage of 2 gallons of carbon tetrachloride per 1,000 bushels as a check, methylene chloride, trichloroethylene, tetrachlorethane, and a 3:1 mixture of ethylene dichloride and carbon tetrachloride failed to give satisfactory kills at the dosages used in these experiments except in one bin, (5-8).

Part 2. Experimental Fumigation of Wheat Stored in Wooden Ever-Normal Granary Bins and Wooden Farm Granaries. (Table 8, part 2.)

Due to the great differences in the construction and tightness of farm granaries, it is difficult to make comparisons of the effectiveness of various fumigants. However, from the data given in table 8, part 2, it would appear that a mixture of carbon tetrachloride, 90 per cent and ethylene dibromide, 10 per cent, is an effective fumigant for farm stored grain at dosages of 2 to 4 gallons per 1,000 bushels, depending on the tightness of the granary. (The ethylene dibromide used in this work was supplied through the cooperation of the Dow Chemical Company).

The role of ethylene dibromide is that of a surface toxicant. In steel bins it is unusual to find a heavy surface infestation and so carbon tetrachloride is an effective fumigant when used alone. However, in wooden granaries cadelles are usually found in the surface grain and near the walls. Under such conditions carbon tetrachloride failed to give complete kills of the cadelles. The mixture of 10 per cent ethylene dibromide and 90 per cent carbon tetrachloride effected nearly perfect kills of all species under these conditions.

Table 8: -- Experimental fumigation of wheat, Hutchinson, Kansas, 1944

Bin No.	Capacity (bushels)	Date treated	Dosage per 1,000 bu.	Per cent mortality: Test probes	Per cent mortality: Natural population
PART I. STEEL BINS		Carbon tetrachloride			
8-12	1000	10/4	2	99.2	96
		Methylene chloride			
1-1	1000	10/20	3	52.0	65
5-8	2740	10/20	3	92.0	96
		Trichlorethylene			
6-6	2740	11/9	2	67.9	83
		Tetrachlorethane			
6-2	2740	11/9	3	44.0	8
9-4	2740	11/9	3	57.1	35
		Ethylene dichloride - 75% Carbon tetrachloride - 25%			
2-16	1000	10/4	2	66.8	87
PART 2. WOOD BINS		Carbon tetrachloride			
13-1	1500	10/5	2	94.7	69
337	1500	11/10	2	58.0	0
Stohle	1500	10/5	3	95.8	--
Walsten	700	10/5	3	66.4	66
336	1500	11/10	3	73.3	--
		Ethylene dichloride - 75% Carbon tetrachloride - 25%			
13-3	1500	11/9	3	64.4	--
13-6	1500	11/9	3	58.9	36
Julius	450	10/5	3	89.7	80

(continued)

Table 8, continued.

Bin No.	Capacity (bushels)	Date treated	Dosage per 1000 bu.	Per cent Mortality: Test probes	Per cent Mortality: Natural population
		Ethylene dichloride			
13-4	1500	11/9	3	49.6	--
		Ethylene dichloride -- 67.5%			
		Carbon tetrachloride -- 22.5%			
		Ethylene dibromide -- 10%			
Pennington	560	10/5	3	99.8	20
Dade	500	10/13	4	98.1	100
		Ethylene dichloride -- 71%			
		Carbon tetrachloride -- 24%			
		Ethylene dibromide -- 5%			
Pennington	670	10/5	3	96.0	0
13-7	1500	10/18	3	86.4	86
		Carbon tetrachloride -- 95%			
		Ethylene dibromide -- 5%			
Hodgson	500	10/5	3	97.8	25
Kirkpatrick	1500	10/5	3	87.9	40
		Carbon tetrachloride -- 90%			
		Ethylene dibromide -- 10%			
Swanson	1300	10/5	2	97.5	98
Kirkpatrick	1300	10/5	3	98.1	70
Walsten	500	10/5	3	96.5	75
Swanson	1300	10/5	4	99.6	100
Dade	500	10/13	4	100	98

Rate of Penetration of Fumigants in Stored Wheat

During the past quarter, further observations were made on the rate of penetration of fumigants in wheat stored in steel bins, in wooden Ever-normal Granary bins, and also in wooden farm granaries. The rate of penetration of the gas was determined by placing test probes containing living insects in the grain. A sufficient number of probes were put in the grain so that one probe could be withdrawn at one-hour intervals after fumigation and the insect mortality determined at various levels, until the maximum kill had been effected.

Six compounds and mixtures were used. The rate of penetration, as evidenced by mortality at various levels, are given in table 9.

In general, the results indicate that in tight bins the vapors of the fumigants used in these tests reach the bottom of the bin within 3 to 4 hours after application to the grain surface. However, in loosely constructed wooden bins, with grain surfaces exposed to outside air currents, the gas may be dissipated before a lethal concentration can be attained in any or all parts of the grain mass.

Table 9:--Rate of penetration of various fumigants in wheat stored in steel and wooden bins, Hutchinson, Kansas, October, 1944.

No. hours after fumigation	Per cent mortality 24 hrs. after removal from bin: 6 ft. level	4 ft. level	3 ft. level	2 ft. level	Floor	Mean
Carbon tetrachloride, 2 gals. per M/bu. 1000 bu. steel bin, 7' grain						
1	51.9		20.0		24.1	31.4
2	100		45.7		39.7	63.5
3	100		100		74.1	92.2
4	100		95.8		93.2	95.8
5	100		100		96.8	99.0
6	100		100		100	100
7	100		100		100	100
Carbon tetrachloride--25%; Ethylene dichloride--75%, 4 gals. per M/bu., 1000 bu. steel bin, 7' grain						
1	100		16.2		14.9	55.9
2	100		34.1		14.7	61.6
3	100		69.8		10.2	57.7
4	100		53.1		55.3	68.6
5	100		56.3		42.0	63.4
6	100		100		61.7	82.6
7	100		97.2		59.7	85.8
24	100		98.6		93.4	97.6
48	100		100		100	100
Methylene chloride, 3 gals. per M/bu., 1000 bu. steel bin, 7' grain						
0.5	83.6		14.5		21.3	42.9
1.5	49.1		21.7		16.4	29.1
2.5	100		32.5		63.9	66.4
3.5	86.4		24.4		55.9	54.7
4.5	63.4		30.8		31.7	39.7
5.5	97.8		95.8		43.2	82.1
6.5	48.1		61.5		25.4	47.0
24	85.4		46.2		58.9	63.2
Carbon tetrachloride, 2 gals. per M/bu., 1500 bu. wood bin, 9' grain						
1	100		69.2		27.4	70.0
2	100		97.2		76.7	93.3
3	100		98.0		94.3	97.6
4	100		100		99.1	99.5
5	100		97.7		89.5	96.4
6	100		100		97.1	99.4
7	100		98.9		100	99.7
Carbon tetrachloride, 3 gals. per M/bu., 700 bu. wood bin, 5' grain						
1		30.3		15.2	11.6	18.9
2		35.6		57.7	34.1	44.4
3		31.1		13.7	16.7	18.9
4		13.2		38.8	11.3	20.0
5		47.4		61.2	--	--
6		50.0		89.7	22.8	55.1
7		55.3		30.6	10.9	29.7

(continued)

Table 9, continued

No. hours after fumigation	Per cent mortality 24 hrs. after removal from bin: 6 ft. level	4 ft. level	3 ft. level	2 ft. level	Floor	Mean
Carbon tetrachloride, 90%; ethylene dibromide, 10%, 3 gals. per M/bu., 500 bu. wood bin, 8' grain						
1	98.4		27.3		21.7	49.5
2	91.4		22.0		15.2	45.9
3	93.6		56.9		50.0	65.1
4	100		76.5		36.0	61.8
5	100		69.7		67.4	78.6
6	100		100		78.2	94.3
7	70.7		83.7		75.0	78.2
24	100		94.4		77.6	90.7
Carbon tetrachloride, 90%; ethylene dibromide, 10%, 4 gals. per M/bu., 500 bu. wood bin, 8' grain						
0.5	86.5		80.0		90.6	85.0
1.5	100		--		94.7	--
2.5	100		93.3		86.9	92.8
3.5	100		100		97.6	99.2
4.5	100		100		98.1	99.5
5.5	100		100		95.0	98.2
6.5	100		100		92.4	97.7
7.5	100		100		96.1	98.6
Carbon tetrachloride, 95%; ethylene dibromide, 5%, 3 gals. per M/bu., 500 bu. wood bin, 5' grain						
1		70.4		32.1	32.7	43.0
2		95.6		40.8	53.7	62.2
3		75.0		15.8	52.2	44.0
4		71.4		27.9	78.9	64.9
5		78.7		28.2	73.2	59.3
6		--		41.2	72.5	--
7		68.0		85.5	29.2	62.0
Carbon tetrachloride, 22.5%; ethylene dichloride, 67.5%; ethylene dibromide, 10%; 4 gals. per M/bu., 500 bu. wood bin, 8' grain						
0.5	100		90.9		86.5	91.3
1.5	100		96.0		86.8	95.0
2.5	100		92.0		65.4	85.1
3.5	100		81.5		89.1	89.9
4.5	100		96.4		96.3	97.7
5.5	100		97.9		100	99.3
6.5	100		100		88.9	96.6
7.5	100		100		98.0	99.5
Unfumigated control, 1000 bu. steel bin						
2						1.0
4						2.6
6						5.3

Effect of Magnesium Oxide, Almicide, and DDT on the Germination of Wheat*

In order to test the effect of the long time exposure of wheat to magnesium oxide, Almicide, and DDT, a series of tests using 12, 14, and 16 per cent moisture wheats were set up.

Seven months have elapsed since these tests were started. Table 10 summarizes the results of monthly germination tests.

Twelve per cent moisture wheat shows no loss in germination when treated with dosages, of either of the three chemicals, sufficiently high to insure protection against insect attack.

Fourteen per cent moisture wheat shows some loss in germination, but in most cases this loss is negligible, and when compared with the 14% moisture check, all three chemicals give indications of having some germicidal value.

Table 10: -- Effect of chemical dusts on the germination of wheat.

Treatment		Per cent moisture wheat	Percentage of germination after: 1 Month	2 Months	3 Months	4 Months	5 Months	6 Months	7 Months
MgO_2	0.05%	12	92	92	90	88	96	95	96
do	0.1%	12	90	92	90	93	93	95	98
do	0.2%	12	89	93	90	94	95	90	90
do	0.05%	14	88	91	85	86	76	82	79
do	0.1%	14	90	90	87	84	84	83	89
do	0.2%	14	93	87	92	83	83	84	82
do	0.2%	16	92	84	77	78	75		
DDT (Conc.)	0.05%	12	91	95	93	86	89	96	93
do	0.1%	12	91	88	90	90	92	94	93
do	0.2%	12	90	90	90	95	95	95	91
do	0.2%	14	93	84	89	90	89		
do	0.2%	16	89	74	78	78	65		
Almicide	0.2%	14	95	85	80	89	82		
do	0.2%	16	94	69	77	74	68		
Check		12	87	86	93	87	94	93	93
do		14	88	82	87	75	71	65	64
do		16	91	86	70				

* -- Reported by J. C. Frankenfeld.

Magnesium Oxide for Seed Treatment*

In previous tests described in Report No. 12, pages 22-25, it was shown that magnesium oxide, with a surface-mean particle diameter of less than 0.25 micron, gave excellent protection to seed from insect attack when mixed with seed at the rate of 0.1 per cent by weight or more. In view of the work of British scientists with inert dusts which indicated that particle size was closely correlated with insecticidal properties, it seemed desirable to experiment with various commercial samples of magnesium oxide to determine whether or not there were any great differences in their insecticidal efficiency.

With the assistance of Dr. R. C. Roark, Chief of the Division of Insecticide Investigations, and various chemical companies, a representative number of magnesium oxide and related dusts were assembled and tested under laboratory conditions, to determine their relative efficiency in protecting wheat seed from the attack of the rice weevil. The rice weevil was chosen as the test insect since the immature stages are concealed within the seed and are not subject to the action of the dust. This feature makes it more difficult to control with dusts than free-living species of grain infesting insects.

Tests were conducted at room temperature, 70° to 75° F., with wheat of 12 per cent moisture content.

Five hundred-gram samples in duplicate were treated with each dust at the rate of .05 per cent and 0.1 per cent by weight and infested with 100 rice weevil adults. Observations were made at weekly intervals until a complete mortality of the insects was obtained or the treatment was found to be ineffective. The results of these examinations are given in tables 11 and 12.

*-Reported by R. T. Cotton and J. C. Frankenfeld.

Table 11.--Insecticidal action of magnesium oxides and other dusts against the rice weevil in seed wheat of 12% moisture content. 500-gram lots of seed treated at rate of 0.5% by weight and infested with 100 rice weevil adults.

Material	Cost per lb.	Particle size S.M.D. microns	Per cent kill at end of week No. 1	2	3	4	5	6	7	Number progeny after 10 wks.
	$									
G. M. & M. extra light	.25	-0.2	37	63	73	89	97	97	100	79
calcined magnesia		-0.2	36	58	70	80	89	100		97
K. & M. Co. light calcined		-0.2	60	82	86	93	96	98	100	14
magnesia		-0.2	56	78	87	92	98	98	100	7
Michigan #30 light calcined		0.2	84	100						14
magnesia tech.		0.2	83	100						16
Baker Chem. Co. magnesium	2.25	-0.25	83	100						18
oxide powdered		-0.25	93	100						9
Westvaco magnesia #2663 Pwd.	.025	0.4	43	70	78	96	100			23
do		0.4	47	68	84	95	100			14
Westvaco #2665 magnesite	.025	0.4	54	84	92	98	100			28
powdered chemical grade		0.4	32	60	90	96	100			31
Westvaco magnesol (Syn.	.04	0.4	77	93	98	98	100			58
magnesium silicate)		0.4	87	96	97	98	100			51
Michigan #15 Heavy calcined	.03	0.4	42	90	100					43
magnesia Tech.		0.4	62	93	100					8
Schundler's #2665 Seawater	.045	0.5	34	52	79	92	100			49
magnesite		0.5	26	43	73	92	100			71
G. M. & M. heavy calcined	.08	0.6	35	63	90	100				41
magnesia		0.6	45	76	97	99	100			49
Westvaco #2665 magnesite		0.6	4	24	77	96	100			76
(99% through 325 mesh)		0.6	37	62	88	100				62
Golwynne's Shamva heavy	.08	0.8	18	37	74	91	100			41
calcined magnesite		0.8	32	60	84	96	100			28
Schundler's Sierra Oxy-	.045	1.9	21	35	52	77	97	100		118
chloride magnesite		1.9	17	29	39	80	96	100		65
Schundler's #2661 Seawater	.0425	3.4	9	9	9	21	41	67	90	333
magnesite		3.4	4	9	9	16	39	74	94	254
Monsanto's Ferrophosphorus		8.0	0	4	6	6	8	15	37	300
Lot D900		8.0	3	4	4	5	6	24	36	263
Check			2	3	12	17	19	20	20	665
Check			0	0	15	19	19	24	24	720

Table 12:--Insecticidal actions of magnesium oxides and other dusts against the rice weevil in seed wheat of 12% moisture content. 500-gram lots of seed treated at rate of 0.1% by weight and infested with 100 rice weevil adults.

Material	Cost per lb.	Particle size S.M.D. microns	Percent kill at end of week number 1	2	3	4	No. of progeny after 10 wks.
G.M. & M. extra light calcined magnesia	$0.25	-0.2	87	100			0
do		-0.2	86	90	100		0
K. & M. Co. light calcined magnesia		-0.2	100				0
do		-0.2	100				0
Michigan #30 light calcined magnesia tech.		0.2	95	100			0
do		0.2	96	100			0
Baker Chem. Co. magnesium oxide, pwd.	2.25	-0.25	86	100			0
do		-0.25	93	97	100		0
Westvaco magnesia #2663 powdered	.025	0.4	100				0
do		0.4	100				0
Westvaco #2665 magnesite pwd. Chem. grade	.025	0.4	100				0
do		0.4	100				0
Westvaco Magnesol (Syn. magnesium silicate)	.04	0.4	97	100			0
do		0.4	100				0
Michigan #15 Heavy calcined magnesia tech.	.03	0.4	86	98	100		0
do		0.4	83	99	100		2
Schundler's #2665 seawater magnesite	.045	0.5	97	98	100		0
do		0.5	88	96	98	100	0
G.M. & M. heavy calcined magnesia	.08	0.6	93	97	100		0
do		0.6	80	95	100		0
Westvaco #2665 magnesite 99% through 325 mesh		0.6	100				0
do		0.6	98	100			0
Golwynne's Shamva heavy calcined mag.	.08	0.8	100				0
do		0.8	100				0
Dow Chem. Co. Sample No. 2		1-2	87	100			0
do		1-2	87	99	100		0
Dow Chem. Co. Sample No. 3		1-2	95	100			0
do		1-2	92	100			0
Dow Chem. Co. Sample No. 4		1-2	94	100			3
do		1-2	93	100			0
Schundler's Sierra oxychloride magnesite	.045	1.9	70	81	94	100	0
do		1.9	63	86	96	100	0
Schundler's #2661 seawater magnesite	.0425	3.4	19	27	30	65	4
do		3.4	10	16	19	40	3
Monsanto's Ferrophosphorus Lot D900		8.0	4	5	8	9	1
do		8.0	4	5	10	10	5
Monsanto's Aluminous oxide D901		11.0	5	6	12	12	2
do		11.0	4	7	8	21	5
Check			0	0	0	0	60
do			0	0	0	0	98

G. M. & M. -General Magnesite and Magnesia Co.
K. & M. Co. - Keasby and Mattison Co.

From the data of tables 11 and 12, it is evident that a wide range of commercial grades of magnesium oxide are effective in protecting seed wheat from the attack of the rice weevil when used at the rate of 0.1 per cent by weight. A dosage of 0.05 per cent by weight, although effective in killing the adult weevils, did not kill them rapidly enough to prevent some reproduction. In general, the magnesium oxides with a surface-mean diameter particle size of less than 1 micron were the most effective and afforded satisfactory protection at the .1 per cent by weight dosage.

The cost of these materials varied from 2½ cents per pound to $2.25 per pound with many of the cheaper compounds being just as effective as the more expensive ones.

Voluminosity, while important, did not appear to be directly correlated with efficiency, e.g., Golwynne's Shamva heavy calcined magnesia tech. with a voluminosity of 60 cubic inches per pound killed as rapidly as Keasby and Mattison's light calcined magnesia with a voluminosity of 470 cubic inches per pound and slightly more rapidly than G. M. & M. extra light calcined magnesia with a voluminosity of 660 cubic inches per pound.

Tests have been started with Michigan #15 heavy calcined magnesia to determine its effectiveness against insects other than the rice weevil. This material was chosen on account of its low cost. Results of these tests with the confused flour beetle and the cadelle are given in table 13.

Table 13: -- Insecticidal action of Michigan #15 heavy calcined magnesia against the confused flour beetle and the cadelle. 500-gram samples of 12% moisture wheat infested with 100 adult flour beetles or 25 cadelle larvae.

Dosage magnesia by weight	Insect	Per cent kill at end of week No. 1	3	4	5
.05%	Flour beetle	0	.5	24	
.1%	do	1	23	84	
.2%	do	33	100		
Check	do	0	0	0	
.1%	Cadelle	16	44		52
.2%	do	0	20		64
Check	do	0	0		16

From the data of table 13 it is evident that the magnesium oxide did not kill the flour beetle adults or the cadelle larvae as rapidly as the rice weevil. However, no reproduction of these free-living species occurred so that it is logical to assume a dosage of .1% by weight would eventually destroy infestations of these species that might be in the seed and would protect the seed from further infestation.

Field Tests

Field tests with inert and chemical dusts are now underway at the Ft. Hays Experiment station, Hays, Kansas. Large quantities of high grade sorghum, wheat, barley, and oat seed were available for treatment and seed was treated in bushel lots, resacked in cotton bags and placed in the seed warehouse of the experiment station. The longtime storage of this seed will provide a real test of the efficiency of dusts in protecting seed from insect damage. In addition to the Michigan #15 heavy calcined magnesia, DDT in combination with this material, pyrophyllite and micro mag* to make a 3 per cent mixture was included for comparative purposes. Treatments given the various seeds are listed below.

Numbers	Seed	Quantity	Dust used	Amount dust added per bu.
1-4	Wheat	1 bu.	Michigan #15 heavy calcined magnesia	.1% by wt.
5-6	do	do	3% DDT in Mich. #15 H. C. Magnesia	do
7-8	do	do	do	.05% by wt.
9-10	do	do	3% DDT in Micro mag	.1% by wt.
11-12	do	do	do	.05% by wt.
13-14	do	do	3% DDT in pyrophyllite	.1% by wt.
15-16	do	do	do	.05% by wt.
17-20	do	do	Check	
21-23	Sorghum	1 bu.	Michigan #15 heavy calcined magnesia	.1% by wt.
24-27	do	do	3% DDT in Mich. #15 H. C. Magnesia	do
28-31	do	do	do	.05% by wt.
32-33	do	do	3% DDT in Micro mag	.1% by wt.
34-35	do	do	do	.05% by wt.
36-37	do	do	3% DDT in pyrophyllite	.1% by wt.
38-39	do	do	do	.05% by wt.
40-41	do	do	Check	
42-51	Barley	1 bu.	Michigan #15 heavy calcined magnesia	.1% by wt.
53	do	do	Check	
54-56	Oats	1 bu.	Michigan #15 heavy calcined magnesia	.1% by wt.

* = Micro mag = 36.0% magnesium oxide and 63.7% calcium hydroxide.

Effect of Fumigation on Baking Quality

In connection with our experimental work on the effect of fumigants on the germination and baking quality of wheat which was summarized in Report No. 13, pages 24 to 28, it is of interest to record data obtained on changes in fat acidity and baking values of wheat stored at Jamestown, North Dakota. One series of 9 bins received an annual fumigation with a 3-1 mixture of ethylene dichloride and carbon tetrachloride, plus 10% methyl bromide, at a dosage of 2 gallons per 1,000 bushels. Another similar series received no treatment. Samples of wheat for baking tests, fat acidity tests, and germination tests, were taken from all bins at the time of the annual fumigation for the years 1941, 1942, and 1943.

In the fumigated series an average loss of viability of more than 50 percent occurred over the 3-year period whereas in the unfumigated series the average loss in viability was less than 10 per cent.

Changes in fat acidity and baking values of the wheat in the two series of bins are indicated in tables 14 and 15.

The data of tables 14 and 15 indicate little difference between the various lots of wheat with respect to changes in baking values and fat acidity regardless of whether or not the wheat was fumigated or whether the germination was reduced as a result of fumigation. When baked by Method No. 2 most wheats showed a gradual loss in loaf volume over a 3-year period, whereas when baked by Method 3a, a general increase in loaf volume resulted. This agrees well with the results of our experimental work summarized in Report No. 13.

Table 14: -- Changes in fat acidity and baking values of wheat stored at Jamestown, North Dakota and fumigated once annually with ethylene dichloride - carbon tetrachloride - methyl bromide mixture.*

Bin No.	Loaf volume by baking method No. 2 (cc)			Difference in loaf volume	Loaf volume by baking method No. 3a (cc)			Difference in loaf volume	Fat acidity		
	1941	1942	1943	1941-43	1941	1942	1943	1941-43	1941	1942	1943
R-1	963	936	916	-47	962	962	936	-26	22.2	28.5	36.8
R-2	861	879	789	-72	871	914	882	+11	21.07	29.7	39.2
S-1	885	876	830	-55	871	920	898	+27	19.3	23.9	33.4
P-5	968	985	983	+15	1000	971	950	-50	14.7	25.1	34.4
Q-5	994	954	914	-80	950	968	986	+36	18.2	26.8	38.9
R-5	905	933	917	+12	882	954	985	+103	20.95	27.4	39.5
S-4	862	888	795	-67	832	882	876	+44	22.83	27.3	35.6
G-5	862	836	781	-81	844	876	883	+39	23.9	27.8	29.9
H-5	865	-	755	-110	914	-	905	-9	17.1	-	33.0

Table 15: -- Changes in fat acidity and baking values of wheat stored at Jamestown, North Dakota without treatment.*

Bin No.	Loaf volume by baking method No. 2 (cc)			Difference in loaf volume	Loaf volume by baking method No. 3a (cc)			Difference in loaf volume	Fat acidity		
	1941	1942	1943	1941-43	1941	1942	1943	1941-43	1941	1942	1943
J-1	902	908	853	-49	965	936	945	-20	20.85	26.2	32.0
K-1	920	873	882	-38	934	971	992	+58	23.6	28.4	38.4
K-2	945	914	856	-89	937	943	950	+13	21.61	22.8	31.0
P-3	936	879	911	-25	920	897	885	-35	19.4	28.6	37.7
Q-3	899	922	873	-26	914	916	925	+11	18.1	27.3	35.0
R-3	847	899	842	-5	925	982	925	0	19.97	27.3	34.4
S-2	948	945	897	-51	928	950	968	+40	18.2	28.6	38.9
G-3	812	812	792	-20	885	954	926	+41	22.8	26.3	32.2
H-3	908	899	-	-	914	928	-	-	15.9	26.3	-

* - Data from U. S. D. A. Baking and Milling Laboratory, Washington, D. C.

Effect of Temperature and the Moisture Content of Wheat Upon the Survival and Reproduction of the Granary and Rice Weevils

On pages 35 and 37 of Report No. 13 we discussed the effect of temperature and grain moisture on the granary and rice weevils when held at a constant temperature of 60° F. At the time that report was prepared this series of tests had been in operation for 13 weeks. The work herewith reported is a continuation of the above described tests. In table 16 is listed the percentage of survival of adult weevils at the end of 15, 17, and 19 weeks. As was indicated in the previous report, the percentage of survival of both the granary and rice weevil increases as the moisture content of the wheat is increased. In the 9% moisture wheat there was only a very small percentage of survival in the case of the rice weevil after the first week. By the end of the 13th week all adults had died.

Although a comparatively high survival of the granary weevil is noted, reproduction by this species at 60° F. is very light, and then only in the 12, 13, and 14% moisture wheats. In the case of the rice weevil, no reproduction occurred in the 9 and 10% wheats; a small amount in the 11 and 12% wheats; and a fairly heavy reproduction in the 13 and 14% wheats. With both species the tendency, even at a temperature of 60° F., is for increased reproduction as the moisture content of the wheat is increased. See tables 17 and 18.

It is interesting to note that in the case of the granary weevil no reproduction occurred until the 10 and 11th weeks. This delayed reproduction on the part of the granary weevil was likewise observed in the tests conducted at a constant temperature of 65° F.

Since both the granary and rice weevil reproduced at 60° F., our investigations were continued by reducing the temperature to 55° F., using the same moisture variants. This new series of tests has been in progress for seven weeks, and the results of biweekly examination are listed in table 19. Again, as in the tests conducted at a constant temperature of 60° F. the percentage of survival increases as the moisture content of the wheat is increased. A higher percentage of survival at each moisture variant is noted for the granary weevil as compared to the rice weevil.

No reproduction at any moisture level for either the granary or rice weevil has been obtained to date.

Table 16: -- Percentage of survival of the granary and rice weevil at 60° F. in wheat of various moisture content.

Moisture content of wheat and Insect used	Percentage survival after 15 Weeks	17 Weeks	19 Weeks	Average survival after 19 weeks	Total reproduction
9% Wheat					
Granary weevil	20	14	10		0
do	16	10	4	7	0
Rice weevil	0	0	0		0
do	0	0	0	0	0
10% Wheat					
Granary weevil	50	50	40		0
do	50	50	36	38	0
Rice weevil	14	8	0		0
do	14	14	2	1	0
11% Wheat					
Granary weevil	86	86	80		0
do	88	82	70	75	0
Rice weevil	52	48	6		40
do	40	36	2	4	26
12% Wheat					
Granary weevil	72	72	72		27
do	82	80	78	75	31
Rice weevil	32	28	20		58
do	24	16	16	18	8
13% Wheat					
Granary weevil	92	90	90		61
do	96	96	96	93	27
Rice weevil	60	58	46		412
do	66	58	54	50	514
14% Wheat					
Granary weevil	92	92	92		60
do	92	92	84	88	59
Rice weevil	76	74	66		323
do	72	70	64	65	951

Table 17: -- Biweekly reproduction of the granary weevil at 60° F. in wheat of various moisture content.

Moisture content of wheat	Number of progeny produced during: 1st Week	2nd & 3rd Week	4th & 5th Week	6th & 7th Week	8th & 9th Week	10th & 11th Week	12th & 13th Week	14th & 15th Week	16th & 17th Week	18th & 19th Week	Total	Ave.
9%	0	0	0	0	0	0	0	0	0	0	0	
9%	0	0	0	0	0	0	0	0	0	0	0	0
10%	0	0	0	0	0	0	0	0	0	0	0	
10%	0	0	0	0	0	0	0	0	0	0	0	0
11%	0	0	0	0	0	0	0	0	0	0	0	
11%	0	0	0	0	0	0	0	0	0	0	0	0
12%	0	0	0	0	0	0	3	9	15	0	27	
12%	0	0	0	0	0	0	3	11	17	0	31	29
13%	0	0	0	0	0	5	11	19	26	0	61	
13%	0	0	0	0	0	0	0	6	21	0	27	44
14%	0	0	0	0	0	0	0	11	49	0	60	
14%	2	1	0	0	0	0	2	16	38	0	59	59.5

Table 18: -- Biweekly reproduction of rice weevil at 60° F. in wheat with various moisture content.

Moisture content of wheat	Number of progeny produced during: 1st Week	2nd & 3rd Week	4th & 5th Week	6th & 7th Week	8th & 9th Week	10th & 11th Week	12th & 13th Week	14th & 15th Week	16th & 17th Week	18th & 19th Week	Total	Ave.
9%	0	0	0	0	0	0	0	0	0	0	0	
9%	0	0	0	0	0	0	0	0	0	0	0	0
10%	0	0	0	0	0	0	0	0	0	0	0	
10%	0	0	0	0	0	0	0	0	0	0	0	0
11%	0	13	0	4	20	1	2	0	0	0	40	
11%	0	10	0	4	10	0	0	2	0	0	26	33
12%	3	6	0	25	22	0	0	0	0	0	58	
12%	0	0	0	0	8	0	0	0	0	0	8	32
13%	4	69	0	73	150	49	35	17	15	0	412	
13%	6	64	1	88	171	70	57	28	29	0	514	463
14%	7	63	6	64	121	23	24	8	7	0	323	
14%	16	127	5	148	313	118	111	47	66	0	951	637

Table 19: -- Percentage of survival of the granary and rice weevils at 55° F. in wheat of various moisture content.

Moisture content of wheat and insect used	Percentage of survival after: 1 week	3 weeks	5 weeks	7 weeks
9% Wheat				
Granary weevil	74	32	16	0
do	74	28	16	8
Rice weevil	50	0		
do	52	0		
10% Wheat				
Granary weevil	90	58	44	30
do	92	62	52	44
Rice weevil	62	12	6	0
do	62	16	10	6
11% Wheat				
Granary weevil	88	86	72	58
do	92	66	66	60
Rice weevil	74	46	34	34
do	80	48	30	26
12% Wheat				
Granary weevil	98	80	78	64
do	90	78	68	62
Rice weevil	82	68	62	58
do	92	72	60	50
13% Wheat				
Granary weevil	90	86	82	82
do	100	98	98	90
Rice weevil	96	76	72	72
do	100	86	76	74
14% Wheat				
Granary weevil	100	100	98	96
do	100	98	96	94
Rice weevil	94	86	78	66
do	98	76	76	68

Effect of Temperature, Moisture, and Dockage on the Survival and Reproduction of T. castaneun

On pages 30-32 of Report No. 13, are given the results of the effect of grain moisture and dockage on T. castaneun when held at a constant temperature of 90° F. for eight wooks. These tests were continued and completed during the interim of this report. For convenience the weekly record of survival for the series for the first 8 weeks is repeated in table 20, together with the record of the final eleven weeks. It will be noted that as the moisture content of the wheat is increased an increase in survival results. And to a certain extent, for a given moisture content, the percentage of survival increases as the percentage of dockage is increased. This is more pronounced in the lower moisture level wheat. In 15% moisture wheat there is no significant difference in the percentage for the different moisture variant lots.

In table 21 is summarized the weekly recovery of pupae of T. castaneum from the above discussed lots. It will be noted that in general there is a definite increase in the total number of pupae recovered as the moisture content of the wheat and the amount of dockage is increased. The decrease in reproduction in the 15% moisture series, as compared to the 12% series, is probably due to the development of molds which is frequently encountered in wheat with a high moisture content. Those molds are very injurious to the eggs of the flour beetles.

It is interesting to note that reproduction at 90° F. is heaviest during the first three or four weeks. (The time required for development from egg to pupa is between 3 - 4 weeks at 90° F.) After about the 7th week egg laying is practically discontinued in most lots. Just what the cause for this unexpected cessation of reproduction, so early in the life of the adult, is as yet unexplainable.

In another series of tests conducted at a constant temperature of 85° F., table 22, we find practically the same general relationship as in the 90° F. series. Survival and reproduction increase as the moisture content of the wheat is increased, and in the lower moisture level wheat as the dockage is increased.

A more uniform reproduction increase (table 23) with the increase in moisture and dockage occurs at this temperature than at 90° F. However, the total reproduction, lot for lot, is considerably smaller in the 85° F. series. Here again we find that reproduction is confined to the early part of the life of the adult, discontinuing entirely in practically all lots after the tenth week.

In conjunction with the tests on the effect of temperature, moisture, and dockage on the survival and reproduction of T. castaneum accurate records were kept on the length of larval development.

For these records, eggs were sifted from flour infested with adult T. castaneum. These eggs were maintained at a constant temperature of 80° F. until hatched. Newly hatched larvae were then confined in small shell vials with whole wheat flour and placed in incubators at 85° F. and 90° F.

At 85° F. an average of 24.4 days are spent in the larval stage, ranging with individual specimens from 23 to 27 days. At 90° F. an average of 22.5 days are spent in the larval stage, ranging from 20.8 to 23.6 days, showing a reduction of approximately 2 days in the developmental period at 90° F. as compared with the developmental period of 85° F.

Table 20: -- Percentage of survival of the rust red flour beetle in 9, 12, and 15% moisture wheat with varying amounts of dockage at 90° F.

Food media	Percentage of survival after: 1 Week	2 Wks.	3 Wks.	4 Wks.	5 Wks.	6 Wks.	7 Wks.	8 Wks.	9 Wks.	10 Wks.	11 Wks.	12 Wks.	13 Wks.	14 Wks.	15 Wks.	16 Wks.	17 Wks.	18 Wks.	19 Wks.
9% Wheat																			
Clean wheat	100	100	100	100	100	100	90	80	5	1	0								
Same + 0.5% dockage	85	80	80	80	80	75	70	70	70	70	70	65	55	50	40	30	15	5	0
Same + 1.0% dockage	100	100	100	100	100	100	100	100	100	100	90	70	50	45	30	15	10	5	0
Same + 2.0% dockage	95	95	90	90	90	90	90	85	85	85	85	85	85	80	65	40	30	20	15
Same + 4.0% dockage	100	95	95	95	95	95	95	95	95	95	90	90	85	70	65	60	50	40	40
Same + 8.0% dockage	95	95	90	85	85	85	75	70	60	55	45	45	40	25	25	25	25	20	20
12% Wheat																			
Clean wheat	100	100	100	100	100	100	100	100	100	95	95	95	70	40	25	25	20	0	0
Same + 0.5% dockage	100	100	95	95	95	95	95	95	95	95	95	95	95	95	95	80	70	50	35
Same + 1.0% dockage	100	100	95	95	90	90	85	80	80	80	75	60	40	35	25	20	20	20	20
Same + 2.0% dockage	95	95	95	95	95	95	95	95	90	65	60	50	50	50	50	45	45	45	45
Same + 4.0% dockage	100	100	100	100	100	100	100	100	95	95	95	95	95	90	90	70	70	65	55
Same + 8.0% dockage	100	100	100	95	95	95	95	95	95	95	95	95	95	95	75	60	55	55	50
15% Wheat																			
Clean wheat	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	90	90
Same + 0.5% dockage	100	100	100	100	100	100	100	100	100	100	100	100	95	95	95	90	85	85	80
Same + 1.0% dockage	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95	95	95	95
Same + 2.0% dockage	100	100	100	100	100	100	100	100	100	100	100	95	95	95	85	85	85	85	85
Same + 4.0% dockage	100	100	100	100	100	100	95	95	95	90	90	90	85	85	80	80	80	80	80
Same + 8.0% dockage	95	95	95	95	95	90	80	80	80	70	60	60	60	55	55	55	55	55	55

Table 21: -- Weekly recovery of pupae from 9, 12, and 15% moisture wheat with varying amounts of dockage at 90° F.

Food media	Number of pupae recovered after: 1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week	11th week	12th week	13th week	14th week	15th week	16th week	17th week	18th week	19th week	Total
9% Wheat																				
Clean wheat				1	8	10	7	5	2	0	0	0	0	0	0	0	0	0	0	33
Same + 0.5% dock.				1	6	16	13	9	8	3	3	0	0	0	0	0	0	0	0	59
Same + 1.0% dock.				14	21	36	29	19	31	18	9	1	0	0	0	0	0	0	0	178
Same + 2.0% dock.				14	15	27	29	26	25	27	21	6	4	5	0	0	0	0	0	199
Same + 4.0% dock.				31	39	39	33	32	23	19	25	17	10	3	0	1	0	0	0	270
Same + 8.0% dock.				61	61	50	50	77	51	46	35	22	16	21	4	4	0	0	0	498
12% Wheat																				
Clean wheat				42	55	58	22	17	13	13	16	11	7	0	3	0	0	0	0	257
Same + 0.5% dock.			21	103	66	58	28	42	29	31	26	17	17	8	10	2	4	0	0	452
Same + 1.0% dock.			30	129	75	43	21	35	17	15	6	1	0	0	1	2	0	0	0	375
Same + 2.0% dock.			27	138	77	52	32	19	5	7	1	0	1	0	0	0	1	2	2	364
Same + 4.0% dock.			76	146	79	43	39	54	37	32	26	6	3	1	1	0	0	0	1	544
Same + 8.0% dock.			100	271	137	100	53	63	92	51	61	17	16	3	2	0	0	0	0	966
15% Wheat																				
Clean wheat			15	122	93	47	25	51	14	2	1	0	0	0	0	0	0	0	0	370
Same + 0.5% dock.			50	155	63	36	25	19	8	2	1	1	0	0	0	0	0	0	0	360
Same + 1.0% dock.			81	109	72	25	19	63	19	9	0	0	0	0	0	0	1	0	0	398
Same + 2.0% dock.			2	112	41	3	1	1	0	0	0	1	1	1	6	0	0	0	0	370
Same + 4.0% dock.				206	146	36	11	4	0	0	1	0	0	0	0	0	0	0	0	404
Same + 8.0% dock.			38	353	133	16	2	0	0	0	0	1	0	0	0	0	0	0	0	543

Table 22: -- Weekly recovery of pupae from 9, 12, and 15% moisture wheat with varying amounts of dockage at 85° F.

Food media	Number of pupae recovered during																	
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week	11th week	12th week	13th week	14th week	15th week	16th week	17th week	Total
9% Wheat																		
Clean wheat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Same + 0.5% dockage								5	6	0	3	2	1	0	2	1	0	11
Same + 1.0% dockage					1	5	6	2	2	0	0	0	0	0	0	0	0	20
Same + 2.0% dockage					1	8	11	8	3	2	3	0	1	0	0	0	0	37
Same + 4.0% dockage				1	20	34	16	11	9	7	0	1	0	0	0	0	1	99
Same + 8.0% dockage				1	14	16	13	2	2	0	1	1	0	0	0	0	1	50
12% Wheat																		
Clean wheat					9	23	23	17	14	5	2	2	9	2	5	1	0	112
Same + 0.5% dockage					39	59	29	29	18	4	2	3	7	0	3	3	0	196
Same + 1.0% dockage				11	59	63	24	26	9	4	1	0	0	0	0	0	0	197
Same + 2.0% dockage				16	76	66	28	32	6	2	2	9	15	0	3	0	0	255
Same + 4.0% dockage				36	124	83	30	25	23	18	10	12	7	1	2	0	0	382
Same + 8.0% dockage				58	46	107	61	31	9	14	28	19	4	0	2	0	0	379
15% Wheat																		
Clean wheat				8	42	25	23	25	15	3	1	2	0	0	0	0	0	144
Same + 0.5% dockage				31	74	27	6	3	6	5	1	3	0	0	0	0	1	156
Same + 1.0% dockage				60	92	54	16	26	15	15	21	14	15	3	8	0	4	337
Same + 2.0% dockage				67	115	57	14	19	24	30	14	12	11	2	1	0	1	366
Same + 4.0% dockage			1	106	169	89	30	30	20	36	19	33	17	1	0	0	0	551
Same + 8.0% dockage			4	239	193	88	41	23	8	1	0	0	1	0	0	0	0	603

Table 23: -- Percentage of survival of the rust red flour beetle in 9, 12, and 15% moisture wheat with varying amounts of dockage at 85° F.

Food media	Percentage of survival after: 1 Week	2 Wks.	3 Wks.	4 Wks.	5 Wks.	6 Wks.	7 Wks.	8 Wks.	9 Wks.	10 Wks.	11 Wks.	12 Wks.	13 Wks.	14 Wks.	15 Wks.	16 Wks.	17 Wks.
9% Wheat																	
Clean wheat	100	95	95	80	30	15	10	0	0	0	0	0	0	0	0	0	0
Same + 0.5% dockage	100	100	100	100	100	100	100	75	45	45	30	20	15	15	5	0	0
Same + 1.0% dockage	100	100	100	100	100	100	95	75	55	40	35	35	35	30	30	20	15
Same + 2.0% dockage	100	100	100	95	90	90	90	85	85	75	50	40	5	0	0	0	0
Same + 4.0% dockage	100	100	100	100	95	65	60	55	45	40	35	30	20	15	10	10	5
Same + 8.0% dockage	100	100	95	85	85	70	65	50	35	35	35	25	20	15	15	5	5
12% Wheat																	
Clean wheat	100	100	100	100	95	95	95	95	95	60	45	30	0	0	0	0	0
Same + 0.5% dockage	100	100	100	100	100	100	95	95	95	85	80	55	25	20	10	10	0
Same + 1.0% dockage	100	100	100	100	100	100	100	100	100	100	90	80	60	40	40	40	30
Same + 2.0% dockage	100	100	100	100	100	90	85	85	85	85	80	75	65	55	45	40	30
Same + 4.0% dockage	100	100	100	100	100	100	100	100	90	80	80	80	70	65	55	45	35
Same + 8.0% dockage	100	100	95	75	45	40	40	40	40	40	35	35	35	35	35	35	30
15% Wheat																	
Clean wheat	100	100	100	100	100	95	95	95	95	95	95	95	85	80	70	70	65
Same + 0.5% dockage	100	100	100	100	100	100	95	95	95	95	95	95	95	95	95	95	90
Same + 1.0% dockage	100	100	100	100	100	95	95	95	95	95	95	95	95	90	80	70	55
Same + 2.0% dockage	100	100	100	100	100	100	100	100	100	100	95	95	85	85	85	85	85
Same + 4.0% dockage	100	100	100	100	100	100	100	100	100	100	100	100	100	95	80	75	65
Same + 8.0% dockage	100	100	100	100	100	100	100	100	100	100	90	85	80	80	75	75	65